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Pollution Taxation in China: The Impact of Inspections

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This study assesses the effectiveness of the enforcement process used to implement China's main industrial pollution clean-up legislation. Liguo Lin from the School of Economics at the Shanghai University of Finance and Economics is the study's author. Using information from over 135 firms based in Fuzhou, the capital city of the Fujian province, he assesses how companies respond to environmental enforcement inspections and whether these inspections lead to improvements in the firms' environmental performance.

The study finds that many firms under-report their pollution production levels. This happens when they take part in the self-reporting process that is a key stage of China's pollution control system. The study also shows that, while enforcement inspections do improve the veracity of the pollution reports that firms submit, these inspections do not significantly reduce the amount of pollution that firms produce.

The study has important implications for policy makers as it shows that current environmental legislation and enforcement is not working. It shows that in order to control pollution both legislation and enforcement must be reformed to provide incentive for firms to actually reduce the amount of pollution they produce.

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EEPSEA was established in May 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Lao PDR, China, and Papua New Guinea.

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ABSTRACT

This study investigated how manufacturing plants reacted to inspections conducted by environmental authorities under pollution taxation regulations in China. Contrary to similar studies in the US, Canada (Magat and Viscusi, 1990; Laplante and Rilstone, 1996) and even China (Dasgupta et al. 2001), we found that inspections significantly increased the level of verified pollution emissions. This finding has important policy implications in showing that inspections by environmental authorities in China are effective in verifying self-reported pollution levels in industries, but not on lowering such levels. In order to really control pollution, a reform of the existing law is necessary.

1. INTRODUCTION

To reduce industrial pollution and improve environmental quality, governments of developed and developing countries have enacted a large number of environmental regulations since the beginning of the 1970s. However, imposing pollution regulations on manufacturing plants does not necessarily lead to a decrease in pollution or an improvement in environmental quality. In fact, it may even turn out to be ineffective if the regulations are not enforced. Enforcement, in this context, is a set of actions to make regulated agents (polluters) comply with environmental regulations. It comprises not only the monitoring of regulated agents, but also sanctions (such as fines and legal action) against them for non-compliance. Monitoring here refers to the collection and analysis of information on the compliance status of regulated agents based on sources which include but are not limited to inspections, ambient pollution samplings, and self-monitoring reports.

In most countries, the enforcement of environmental regulations involves self-monitoring, that is, manufacturing plants have to report their pollution emissions at regular intervals to government environmental agencies. It is commonly accepted in literature that self-reporting saves a large amount of enforcement resources and improves the regulated agents' compliance with regulations (see Kaplow and Shavell 1994). A question which naturally arises here is: How accurate is self-reporting? Further questions would be whether inspections by environmental authorities make self-reporting more truthful or if they make plants reduce their actual pollution, or both. Inspections here are defined as on-site checks of plants by inspectors sent by official environmental agencies.

This study is on how polluters react to environmental inspections under China's pollution taxation laws. We sought to find out whether the inspections conducted by China's environmental agencies were effective in reducing industrial pollution. Our main finding was that inspections were effective in verifying pollution reports by firms, but not effective in reducing actual pollution emission levels. In order to really control pollution, a reform of the existing regulations is necessary.

The approach commonly taken in literature on this topic is generally based on the Theory of the Economics of Crime developed by Becker (1968). Downing and Watson (1974), Harford (1978), and Storey and McCabe (1980) were the first to apply the Becker theory in the environmental arena while there has been a rapid growth in its theoretical and empirical applications in recent years.

Magat and Viscusi (1990) and Laplante and Rilstone (1996) estimated the impact of inspections on pollution self-reports by pulp and paper plants in the United States (US) and Canada, respectively, where pollution standards are legally imposed. These researchers reported that plant pollution reports by their respective sampled populations reflected the actual situation to a large extent. Magat and Viscusi (1990) showed that inspections permanently reduced the level of industrial pollution by approximately 20% while Laplante and Rilstone (1996) concluded that not only inspections, but also the threat of inspections reduced actual pollution emissions by plants by approximately 28%. Nadeau (1997) further found that inspections significantly reduced the durations of violations of air pollution standards by the pulp and paper industry in the US. Other studies extended the analysis to include other enforcement actions. Shimshacka and Ward (2005, 2007) used data, again from the pulp and paper industry in the US, to analyze the impact of a fine for water pollutant violations. All of these studies confirm theoretical prediction that industrial pollution is a decreasing function of the level of enforcement of pollution standards (see Harford 1978). Therefore, inspections by environmental agencies in the US and Canada have induced industry to ensure that they keep below the pollution standards set.

The environmental regulatory framework in China is very different from the US and Canada. Although there are pollution standards in China, plants can just pay levies if their pollution levels exceed the set limits. Dasgupta et al. (2001) examined whether inspections had an impact on the environmental performance of Chinese polluters. Their dataset involved yearly-based plant-level data and their sample included plants which paid as well as did not pay pollution levies. They found that plant pollution emissions decreased by only a very small degree with inspections. There are also other Chinese studies in this context. For instance, Wang et al. (2002) showed that state-owned firms were subject to less strict enforcement measures by the government compared with private firms, and Wang and Wheeler (2005) found compliance with regulations varied according to plant characteristics (age, location, and so on).

We were interested in studying how inspections explained the environmental performance of the plants in our study. Unlike Dasgupta et al. (2001), however, we adopted a unique dataset with quarterly-based plant-level information on environmental performance. Only plants paying pollution levies were included in our sample. We believe that our dataset has significant advantages over the one adopted by Dasgupta et al. (2001) in that quarterly-based plant-level data would better explain firms' reactions to inspections than yearly-based data. Moreover, we expected plants which paid and did not pay pollution levies to have different reactions to inspections in that paying plants would be more inclined to under-report their pollution emission levels in order to avoid levies.

To the best of our knowledge, our research is the first empirical study to analyze how levy-paying plants react to inspections by environmental authorities (the sampled firms in Magat and Viscusi (1990) and Laplante and Rilstone (1996) did not pay levies).

Our empirical results indicate that with pollution levies, inspections by environmental agencies were found to significantly and positively increase the level of verified pollution emissions[1] by 8.26%. This also suggests that plants generally under-report their pollution emission levels in China.

These findings differ greatly from those of Magat and Viscusi (1990) and Laplante and Rilstone (1996). As we mentioned before, they found that inspections reduced plant-reported pollution figures by a very large margin. They argued that self-reporting by the industries well represented their actual pollution emission status while we treated the plant reports as prima facie information and not equivalent to actual levels. For instance, Laplante and Rilstone (1996) tested and concluded that firms did not systematically under-report their pollution levels, and although Magat and Viscusi (1990) did not do this test, they too reported that the firms' pollution figures in their survey reflected actual levels. The institutional differences between China and the US and Canada explain these dissimilar results well. In particular, the US and Canada implement pollution standards while China uses pollution taxation to deter pollution. Other factors, such as penalties for fraudulent reporting, and environmental authorities' inspection strategies also explain the observation and are discussed more in detail later in this paper.

The rest of this report proceeds as follows: in Section 2, we describe China's environmental regulations in detail; in Section 3, we present our dataset, empirical models and results; and conclusions are given in Section 4.

2. ENVIRONMENTAL MANAGEMENT IN CHINA

China's industrial growth especially in the last three decades or so has been extremely rapid. Since the 1980s, industrial output has increased by more than 10% annually. Industry has become the largest sector in China's economy and now accounts for approximately 50% of China's Gross Domestic Product (GDP). However, with this rapid growth, damage to the environment has become a serious problem and an obstacle to sustainable development. Industry is the primary source of water and air pollution in China today. Almost one third of China's waterways are near biological death from the excessive discharge of organic pollutants and five out of every seven rivers are badly polluted. In many urban areas, atmospheric concentrations of pollutants such as suspended particles and sulfur dioxide routinely exceed World Health Organization (WHO) safety standards by very large margins (Dasgupta, Huq and Wheeler 1997; World Bank 1997). China's State Environmental Protection Agency (SEPA) estimates that industrial pollution accounts for over 70% of the nation's total emissions of pollution (SEPA 1996).

Since the late 1970s, China's national environmental regulations have been designed to reduce industrial pollution and improve environmental quality in a way that is consistent with the average level of social development. The Environmental Protection Law (EPL) was first adopted (on a trial basis) in 1979 by China's legislative authority and

[1] Verified pollution emission levels refer to the amounts of pollution for which the sampled firms actually paid levies on. See also footnote 8.

officially enacted in 1989. In accordance with the EPL, a series of pollution control regulations was implemented and enforced by environmental administration authorities. The pollution control regulations have been amended several times in recent decades[2]. However, they have remained centered around a pollution tax charge which is called the pollution levy system.

2.1 Design and Development of the Pollution Levy System

Before 1993, the pollution levy system formally required that a plant pay a fee only if the quantity of effluent discharge exceeded the legal standard. Moreover, the pollution levy was actually paid only on the pollutant that exceeded its standard by the greatest amount, but not on all the pollutants that exceeded their standards. After 1993, levies at lower rates were imposed on plants that discharged within-standard water and air pollutants. Finally, since 2003, plants are required to pay levies on their three largest pollutants and the levy rates have increased dramatically. These new regulations are aimed at establishing stronger pollution control. Given that our dataset was based on industrial emissions of water pollutants for the year 2002, we will explain the pollution levy system for wastewater in 2002.

In 2002, China's pollution levy system was a two-tier pollution charge system, with uniform rates for within-standard pollution and higher, escalating rates for above-standard pollution. If every pollutant emitted by a plant was below the respective standard for that particular pollutant, the plant had to pay the within-standard levy on the total amount of wastewater discharged[3]. Otherwise, the plant would have to pay the above-standard levy.

The above-standard levy was calculated with respect to those pollutants emitted by plants above their respective standards using the equation below. Now, consider a plant j emitting M number of water pollutants above their respective standards, namely, for each pollutant i (i = 1,...M), with a concentration (C_{ji}) greater than the corresponding legal standard (C_i^*).

$$L_j = \max\{L_{ji}, i = 1,....M\}$$

where,

$$L_{ji} = R_{2i} P_{ji} \text{ (for } P_{ji} \le T_i \text{) and } = L_{0i} + R_{1i} P_{ji} \text{ (for } P_{ji} > T_i \text{)} \qquad \text{(Equation 1)}$$

where, L_{ji} is the estimated levy to be paid by plant j on pollutant i; P_{ji} is the discharge factor of pollutant i calculated as $W_j((C_{ji}-C_i^*)/C_i^*)$, where W_j is the total amount of wastewater discharged by plant j; T_i is the threshold factor that determinates the levy rate adopted; R_{2i} is levy rate applied when the discharge factor P_{ji} is below the threshold while the levy rate R_{1i} (with $R_{1i}<R_{2i}$) is applied for above-threshold pollution; and L_{0i} = [R_{2i}-

[2] The regulations were amended in 1982, 1991, 1993 and 2003.

[3] Since 1993, the standard fee for within-standard pollution of wastewater discharge has been ¥ 0.05 per ton. Within-standard charges have also been imposed on SO_2 emissions since 1996. USD 1≈ ¥7 in this study.

$R_{1i}]T_i$ is a fixed payment that makes the levy function continuous. The potential levy L_{ji} is calculated for each pollutant i and the actual levy L_j is the greatest of the potential levies.

The formula is calculated on a monthly base. To illustrate, we compute Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS) levies for a plant with discharged water concentrations of 140g/l for COD (local standard = 100g/l) and 140g/l for TSS (local standard = 70g/l). The relevant ratio $(C_{ji}-C_i^*)/C_i^*$ is 0.4 for COD and 1 for TSS. The plant's discharge of wastewater W is 100,000 tonnes. Therefore, $P_{COD} = W*0.4 = 40{,}000$ tonne.time and $P_{TSS} = W*1 = 100{,}000$ tonne.time. The tax rates for the two pollutants are R_{1COD} = ¥ 0.05/tonne.time; R_{2COD} = ¥ 0.18/tonne.time; R_{1TSS} = ¥ 0.01/tonne.time; R_{2TSS} = ¥ 0.03/tonne.time. The regulatory threshold parameters for the two pollutants are $T_{COD} = 20{,}000$ and $T_{TSS} = 800{,}000$ given exogenously by the regulation (i.e., they are regulatory parameters set by the regulation/law) and the fixed payment factors are L_{0COD} = ¥ 2,600 and L_{0TSS} = ¥ 16,000. Since $P_{COD}>T_{COD}$ and $P_{TSS}<T_{TSS}$, applying the formula, the potential levies are $L_{COD} = L_{0COD}+R_{1COD}P_{COD}$ = ¥ 4,600, and $L_{TSS} = R_{2TSS}P_{TSS}$ = ¥ 3,000. Since the levy for COD is higher, the plant's water levy charge is ¥ 4,600.

The levy function takes into account both the concentrations of the hazardous pollutants and the amounts of discharged wastewater since it calculates the discharge factor (P_{ji}) based on both the total wastewater discharged and the degree to which pollutant concentration (C_{ji}) exceeds the standard (C_i^*). The standard (C_i^*) is jointly set by central and local government authorities, and it is different across industries and waterways into which the wastewater of the respective plant is discharged. Both levy rates (R_{1i}, R_{2i}) and the threshold factor (T_i) are set by the central government and vary by pollutant, but not by industry or region.[4]

The levy system fails to provide industries with a strong incentive to control pollution. Firstly, the levy system integrates pollution standards and levies. In a way, firms can emit more pollutants by simply paying higher pollution levies. Although, in principle, firms can be penalized for violating the standards, the penalties are only imposed when their pollution levels exceed the legal standards by a large margin. Therefore the legal scenario with regard to pollution control in China is very different from the US and Canada. In the latter, exceeding the approved limits leads to an immediate penalty.

Secondly, the levy system only requires plants to pay levies on the pollutant that exceeds its standard by the greatest amount; therefore, plants may only care about the pollutants they are paying levies for, and not bother about reducing their other pollutants.

[4] The levy formula for air pollution is simpler. The within-standard levy is exactly the same as for the wastewater levy. As for the above-standard air pollution levy, unlike the water levy, it is assessed on the absolute emission amounts, rather than percentage deviation from the concentration standards. For firm j and pollutant i, the potential levy is $L_{ji} = R_iV_j(C_{ji}-C_i^*)$, where R_i is the levy rate; V_j is the total quantity of air pollutant emissions; C_{ji} is the pollutant concentration; and C_i^* is the concentration standard. Again, a firm is assessed only on the highest of its potential levies.

Thirdly, in some cases, a plant can end up paying higher levies even when its emissions are within the standards[5]. Finally, the levy system is not compatible with the principles of environmental economics since the more pollution a plant emits, the cheaper the marginal cost (levy rate) the plant is subject to (i.e., a plant pays its pollution levies according to the cheaper over-standard levy rate, R_1, once its discharge factor is greater than the threshold level T, otherwise the plant pay levies according to the more expensive levy rate, R_2. Note that the above-standard rate is a scaling rate including both R_1 and R_2 differentiated by the threshold level T calculated using Equation 1).

2.2 Implementation of the Levy System

China's State Environmental Protection Administration (SEPA) is a national agency that is empowered and required by law to implement environmental policies and enforce environmental laws and regulations within the different states. In practice, local (municipality and county/district) environmental protection bureaus (EPBs) are responsible for many activities pertaining to the actual implementation of environmental regulations. There are EPBs in all the districts of the municipalities. Municipal EPBs are mainly in charge of relatively big polluters while district EPBs deal with small polluters. Although legally accountable to SEPA, local EPBs depend heavily on local governments for financial and organizational support.

All polluters are required to self-report their pollution emission levels to environmental authorities by providing (a) basic economic information (sector, major products, raw materials, number of employees, and so on); and (b) information on their pollution emissions (amounts of wastewater, air or solid waste discharge, pollutant concentrations, etc.). The polluters' reports are verified by environmental regulation agencies in several ways, including monitoring, conducting inspections, and checking for inconsistencies between material input and output figures, and between present and historical data. Once the reports are verified, levies are calculated and collected by local regulation authorities monthly or quarterly.

The detailed procedures of implementing the levy system are as follows. At the beginning of the year, plants have to register with environmental authorities by providing their predicted quantities of pollution emissions for the year (based on their normal operations). Environmental authorities verify the registration reports and then issue pollution discharge permits to plants. During the year, plants are required to modify their reports should their actual emission levels differ from the predictions submitted at the beginning of the year. Environmental authorities verify plant reports by conducting field inspections. At the end of each quarter, based on the plant reports and inspections, they then notify the plants of the levies that they should pay for that quarter.

[5] In the same framework as in the example given for calculating the wastewater levy, let us assume that a plant's discharged water concentrations are 90g/l for COD (local standard = 100g/l) and 65g/l for TSS (local standard = 70g/l). Hence, the wastewater discharged meets the standard. Again, let us assume that the plant's discharge of wastewater W is 100,000 tonnes. In this way, the plant pays the within-standard levy: W*¥ 0.05/ton = ¥ 5,000. Compared with the wastewater levy charge in the wastewater example, it is obvious that the within-standard levy is even higher than the above-standard levy (¥ 5,000 > ¥ 4,600), in this case.

In case of false information in any of the plant reports, the firms are liable to pay the evaded levy and between 100% and 300% extra as a punitive penalty. When a plant is caught seriously under-reporting its pollution levels, besides the above penalties, it faces an additional fixed penalty. The total monetary penalty should, however, not exceed ¥ 100,000 (around USD 14,286). Although other non-monetary penalties are also available such as revoking discharge permits and shutting down facilities, they are rarely used. Hence, the penalty mainly involves a financial cost with a ceiling. Given this system, plants do not have a strong incentive to report their emission levels truthfully.

3. METHODOLOGY AND RESULTS

3.1 Data Description

The data used in the current empirical analysis was supplied by the Fuzhou Environmental Protection Bureau (FEPB). Fuzhou is the capital city of Fujian Province, which is located in the southeast part of China. Fuzhou's GDP was ¥ 31,582 (around USD 4,511) per capita in 2003, ranking at 21st place among 658 Chinese cities. Over the course of the last decade, Fuzhou's industrial output has increased at an average rate of 12% annually. Fuzhou's eleventh five-year-plan (2006-2010) calls for further development of the food, medicine, chemical, automobile, and textile industries. However, as a result of this rapid expansion, the ambient quality of both air and water has deteriorated. For instance, in 2006, it was found that over 25% of the rain was acid with PH values between 5.0 and 5.6 (FEPB 2007).

We selected the plants for our sample according to the following criteria: (a) they paid levies according to their COD pollution in the year 2002; (b) they belonged to the food, chemical, paper, or medicine industries; and (c) they were supervised by the FEPB[6]. We selected plants that paid levies for COD pollution because COD was the most common pollutant that large plants paid levies on, and we expected the decisions of the managements of these plants to be more sensitive to inspections. We concentrated on the four sectors which the large COD polluters belonged to.

The sampling method, however, presented a possible problem; suppose that because of inspections, a firm had reduced its level of COD discharges and that in 2002, it did not pay pollution levies anymore on COD. By definition, this firm would not be included in the dataset since it did not pay pollution levies in 2002. However, in this case, the fact that it did not pay pollution levies in 2002 on COD was precisely because of the inspections. Thus, selecting only firms which paid pollution levies in 2002 could lead to significantly under-estimating the impact of inspections. So, we checked with the FEPB whether there were firms that paid COD levies in 2001 but not in 2002. We found that such a case was rare and that most firms paid pollution levies consistently on a certain pollutant. Therefore, it is unlikely that the results obtained in this analysis significantly under-estimate the impact of past inspections.

[6] There are many small firms are supervised by county and district level environmental agencies. For instance, in Fuzhou, there are eight counties and five districts with an environmental agency in each of them.

Our dataset was different from the ones used in Dasgupta et al. (2001) and in Wang and Wheeler (2005), who also studied the environmental performance of industries with respect to China's levy system. Compared with the former who used annual data, we used quarterly-based observations and we also added the variable of value of output. Moreover, we only considered plants that paid levies. In Wang and Wheeler (2005), the authors did not include inspections in their analysis.

Table 1 displays some descriptive statistics of our dataset. It contains the emission and production information of 137 plants for the year 2002. The 137 firms were those that satisfied the three criteria discussed above. The variables such as value of output, COD/TSS concentrations and discharges, levy rates, frequency of inspections, and frequency of citizens' complaints, were quarterly-based. Although the rest of variables, i.e., number of workers, age of the plants, sector, and ownership, were annual-based data, we simply treated them as quarterly data because they were not expected to significantly change within a year. The output values were collected from the Fuzhou Bureau of Statistics because the FEPB could only provide annual output values and we expected the variations in the quarterly output values to be an explanatory variable for quarterly changes in the pollution levels of the plants.

Table 1 shows that the quarterly average number of inspections was 2.19 per plant. In fact, almost all the plants suffered at least one field inspection in a quarter and one plant had up to eight inspections. Note that we integrated two kinds of pollutants in our dataset: COD on which the plant paid pollution levies, and TSS that none of the plants paid pollution levies on. Plant TSS discharge concentrations were found to be much less than the COD levels. More than 60% of the sampled plants paid levies according to the low tax rate, so they (honestly) reported COD emissions above the threshold level. We also included citizens' complaints in our dataset. Apart from the normal field inspections, complaints made by citizens regarding environmental pollution incidents may trigger inspections and make plants further comply with environmental regulations. The average quarterly value of output was ￥44.1 million (around USD 6.3 million) and the average number of employees was 443. Chemical firms made up 39% of our sample. Finally, although collective plants (in China, these are firms belonging to a village/town) were the most represented in our sample (45%), state-owned and joint-venture plants were also well represented.

Table 1. Descriptive statistics of sample (quarterly data, 2002)

Variables	**Mean per quarter**	**Standard deviation**
Value of output (10 million yuan)	4.41	6.52
Number of Employees	443.28	321.66
COD discharge (tonnes)	25.37	53.61
TSS discharge (tonnes)	8.68	17.53
COD concentration (mg/l)	310.99	85.92
TSS concentration (mg/l)	145.78	78.15
Age (decades)	2.29	1.31
Inspection (no. of times)	2.19	1.52
Citizen's Complaints (no. of times)	0.07	0.27
Adapt to Low Rate	62%	
Adapt to High Rate	38%	
Food	37%	
Chemicals	39%	
Paper	15%	
Medicine	9%	
State-owned	25%	
Collective	45%	
Joint-venture	30%	
Number of plants	137	
Number of observations	548	

Notes:

(1) COD means Chemical Oxygen Demand and TSS means Total Suspended Solids. Both refer to the water pollutants measured in this study.

(2) Age means how long the firms have been established.

(3) Adapt to Low Rate means the percentage of firms in the sample that paid taxation according to the lower rate R_{1COD} (given that $R_{1COD} < R_{2COD}$), and vice versa for the Adapt to High Rate (R_{2COD}) variable. As shown in Equation 1, there are two above-standard rates for each pollutant: R_{1COD} and R_{2COD} (taking COD as an example).

(4) Food, Chemicals, Paper and Medicine refer to the sectors.

(5) State-owned, Collective and Joint-venture refer to type of ownership.

(6) Number of observations is the number of firms multiplied by 4 because for each firm there were four observations corresponding to the four quarters of the year 2002.

A question which naturally arises with self-reporting is whether the plants accurately report their pollution levels. To some extent, this question can only be answered by those who make the reports: the plant managers themselves. In view of China's levy system, we expected that plants would be more inclined to submit false reports for three reasons. Firstly, the pollution taxation laws in China give polluters a strong financial incentive to try to balance the costs of true reporting (taxes) with possible fines (see also Wang and Wheeler 2005). Secondly, the legal liability for inaccurate reporting by plants is usually only a limited monetary penalty. Finally, the procedures of self-reporting provide plants with some room for under-reporting. According to the FEPB, most plant report estimations at the beginning of the year are significantly lower than the pollution levels they eventually pay for. Therefore, it is likely that the pollution emission data provided by the sampled plants in our study did not reflect the actual scenario.

Enlightened by Laplante and Rilstone (1996), we intended to run a test of differences between the plant self-reports and the inspection data[7]. The on-site inspection data (i.e., the actual inspection records of each visit) were, however, not available to us, but we did have access to the firms' self-reported data for the beginning of 2002 and the pollution amounts the firms paid finally paid levies on (the verified levels). We labeled the emission variables in our dataset as the verified pollution levels of the firms[8] and amended the test by comparing the emission variables with the firms' self-reported data. As indicated in Table 2, the resulting test statistics showed that both self-reported COD concentrations and quantities were significantly below their verified levels. We therefore concluded that firms systematically under-reported their pollution emissions. The reasons for this unsurprising phenomenon have been discussed earlier. It makes it interesting, however, to know how and to what degree inspections can make firms report truthfully (mainly in terms of their modified reports).

Table 2. Paired difference of means test

	COD concentration (mg/l)	**COD pollution (tonne)**
Mean verified measurements	310.9872	25.3651
Mean self-reported measurements	285.6496	23.7757
Difference	25.3376	1.5894
T-statistics (H1: Difference > 0)	18.1959	8.4634

3.2 Models and Results

In this section, we provide the models and regression results in three steps. First, we discuss the ordinary least square (OLS) estimates of the basic model to examine the impact of inspections and then we check for possible biases in the simple OLS

[7] Thanks to Benoît Laplante for making this suggestion.

[8] The emission variables (the verified pollution emissions levels) for a particular quarter were derived from plant self-reports and the results of inspections, whichever was applicable for the respective sampled firms, depending on whether or not they were inspected in that particular quarter.

estimations. Second, we modify our estimations by using a two-staged least square method with an instrument variable. Finally, we compare our results with those from previous studies.

3.2.1 The Basic Model

We first present a simple regression model by using OLS estimations. The objective here is to test for the impact of inspections on two sets of variables: (a) the absolute discharge quantities of COD and TSS; and (b) the levels of COD and TSS discharged relative to their respective standards [9] (namely, those exceeding the corresponding concentration standards). The following equation was used for all calculations – two each for (a) and (b) above.

$$Z_{i,t} = c + \beta_1 INS_{i,t} + \beta_2 INS_{i,t-1} + \beta_3 OPT_{i,t} + \beta_4 AGE_i + \beta_5 EMP_i + \beta_6 RATE_i + \gamma SEC_i + \delta OWN_i + \varepsilon_{i,t}$$

(Equation 2)

where,

$Z_{i,t}$ denotes the emission variable associated with plant i at time t; (In some specifications, $Z_{i,t}$ is the absolute discharge quantity, while in others, it is the quantity of the discharge in excess of the standards. $Z_{i,t}$ may be negative when it represents the plant's relative TSS discharge[10] and when it is within the standard.);

$INS_{i,t}$ stands for inspections performed at plant i at time t (current inspections);

$INS_{i,t-1}$ correspondingly represents inspections at time t-1;

$OPT_{i,t}$ is plant i's value of output at period t[11];

AGE_i gives the age (in number of years) of plant i;

EMP_i is the number of employees in plant i;

$RATE_i$ is a tax rate dummy that takes the value of 1 if plant i pays levies for its COD pollution according to the cheaper rate R_1; and 0 when it pays the more expensive rate R_2;

SEC_i is a matrix of dummies to indicate which sector plant i belongs to (food, chemicals, medicine, or paper); and

OWN_i is a matrix of dummies to represent a plant's ownership.

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[9] The absolute discharge is W*C where W is the total amount of wastewater and C is the concentration of a pollutant. The relative discharge is defined as $W*(C-C^*)$, where C^* is the corresponding concentration standard and $(C-C^*)$ is the discharge exceeding the corresponding concentration standard. The relative discharge is a good measure of how much a firm's pollution discharge deviates from the standard.

[10] We only tested firms which emitted COD over the standard, therefore the relative COD discharge would always be positive. However, this did not necessarily apply to TSS emissions.

[11] We considered using "volume of output" instead of "value of output" since the former was more closely related to pollution. However, we did not have data on the firms' volumes of output or input and we did not want to encounter measurement difficulties by using volume of output since the firms had different kinds of production.

We allowed for plants to be different in their production efficiency (with respect to pollution) in our analyses. Moreover, our model took into account the fact that the independent variables (plant-reported pollution) could be partly explained by the fact that actual pollution levels varied according to output levels. Given that a plant's actual pollution was not observable, the value of output was a good measure of the variation of a plant's actual pollution across quarters due to variations in its production output. We assumed that a plant's reported pollution was a function of its actual pollution for which the value of a plant's output was a proxy.

This model is different from traditional empirical analyses in this context. The value of output variable in our model takes on the same role as the lagged independent variables in previous studies. Laplante and Rilstone (1996) used a 12-period lagged pollution variable and Dasgupta et al. (2001) used a one-period lagged pollution variable. In fact, they acknowledged in their papers that it may have been better to use production output as a regressor in their models, except that the data was not available to them. Under the assumption that there were no drastic changes in the production and pollution abatement technology of the firms during the year 2002, the value of output made a better proxy for actual pollution emissions by a plant. As the emission data in our dataset was partly made up of self-reports and therefore, not expected to be fully reflective of the actual amount of pollutants emitted by the respective plants, using lagged independent variables could cause systematical bias. We also used number of employees, age of plant, sector, and ownership as regressors. Wang and Wheeler (2005) found that these variables significantly explained the difference in industrial pollution quantities across firms.

The results of the above estimations are presented in Table 3. There are four sets of results corresponding to the two measures of two kinds of pollutants. As expected, the coefficients for the value of output variables were positive and showed a strong positive relationship with both COD and TSS pollution discharges, except for the relative TSS discharge. Besides the output value, other factors, such as sector and ownership also showed significant effects on pollution discharge. The coefficients for the sector dummies had very strong negative effects on COD discharge, while there were weaker and ambiguous effects on TSS discharge (negative on absolute TSS discharge but positive on the relative values). The reason is that medicine-manufacturing plants produce more COD than plants in other sectors. Moreover, plants in the medicine sector are comparatively large producers of absolute TSS discharge but not relative TSS discharge, which is the reason why the coefficients for the sector dummies showed ambiguous effects with respect to TSS discharge. Hence, it is not necessarily true that pollution by large polluters deviates more from the standards than emissions by small polluters. State-owned and collective enterprises appeared to produce more pollution, which is not surprising in view of the fact that they usually have lower production efficiencies than plants with joint-venture ownership and also because state-owned plants have much more bargaining power with environmental authorities in the enforcement of pollution charges (see also Dasgupta et al. 2001 and Wang et al. 2002).

Table 3. Results of emission equations (OLS)

(Sample Size: 411[12])

Independent Variable	COD Discharge		TSS Discharge	
	Absolute	Relative	Absolute	Relative
INS_t	2.0532**	1.0974*	0.5694	0.0155
	(0.9367)	(0.6705)	(0.3969)	(0.3599)
INS_{t-1}	-0.3612	-0.6399	0.6364	0.6081
	(1.0314)	(0.7383)	(0.437)	(0.3962)
OPT_t	6.8907***	4.0358***	2.0990***	0.1284
	(0.2758)	(0.1974)	(0.1169)	(0.106)
AGE	1.1226	1.1829	-0.0905	-0.4049
	(1.3655)	(0.9774)	(0.5785)	(0.5246)
EMP	-0.0002	0.0032	-0.0056**	-0.0035
	(0.0062)	(0.0045)	(0.0026)	(0.0024)
Rate	-6.3792**	-3.2934	-0.2427	1.7097
	(3.1447)	(2.2512)	(1.3325)	(1.2082)
Food	-37.9595***	-26.8113***	-5.7401***	2.5821
	(4.6471)	(3.3267)	(1.9691)	(1.7857)
Paper	-34.4710***	-27.8507***	-2.244	3.6405*
	(5.0219)	(3.5949)	(2.2179)	(1.9293)
Chemicals	-28.9541***	-19.8509***	-3.2032*	3.4754**
	(4.2442)	(3.0383)	(1.7984)	(1.6306)
State-owned	14.7699***	6.7475**	7.1409***	2.5958*
	(3.9503)	(2.8278)	(1.6738)	(1.5176)
Collective	9.7196***	5.9849***	2.5566*	0.0475
	(3.1824)	(2.2781)	(1.3485)	(1.2226)
Constant	14.6644**	12.0357***	0.2173	-2.0758
	(5.7726)	(4.1324)	(2.446)	(2.2178)
R^2	0.8224	0.7682	0.6924	0.0508

Note: The second row for each variable shows the standard deviations.

[12] We had 548 (137 firms x 4 quarters) observations, but could not use the first quarter's observations for each firm due to the one-period lagged inspection variable. Therefore 548 - 137 = 411 observations.

The coefficients for the current inspections were positive and significant for COD discharge but insignificant for TSS discharge. This might be because inspections mainly target the pollutant on which plants pay their pollution levies. It also might be that plants react to inspections by only paying attention to the pollutant that they pay pollution taxes on. Current inspections were found to increase verified absolute and relative COD pollution levels by 3.7% and 3.16%, respectively, while one-period lagged inspections showed no significant effect. These results provide strong evidence that plants under-report their pollution, confirming our suspicions that the pollution emission data supplied by the firms in our dataset was not accurate. The results also show that inspections are effective mainly in terms of verifying plant pollution reports rather than being a deterrent in reducing industrial pollution.

On average, there were four observations per plant for 137 plants. One question that naturally arose here was whether the estimated coefficients on inspections accurately explained how a plant reacted to inspections imposed on it. In other words, the coefficients of inspections in the above regressions might have been biased. For instance, if large polluters were inspected more frequently than small ones, the positive coefficients for inspections might just be explained by the fact that large polluters reported more pollution than small ones, and hence the inspection variable was just a proxy for polluter “size” (inter-plant effects). We expected the coefficients for inspections to estimate how a plant's reported pollution reacted to inspections (intra-plant effects). In order to test whether the coefficients for inspections caught inter-plant or intra-plant effects, we ran a simple OLS regression in which we averaged all quarterly variables for the 137 plants. The results are presented in Appendix 1. The average number of plant inspections was shown to have no significant influence on the average COD discharge amount. Therefore, we concluded that the coefficients for the current inspections in Table 3 mainly captured the intra-plant effects.

Another concern in the context of this study was the possible endogeneity of inspections and its effect on the OLS estimates. If inspections were endogenous and correlated with the same variables that determined current pollution levels, then the OLS estimations would be biased. Put another way, inspections by environmental agencies themselves could be somehow triggered by plant pollution levels. Given this potential problem, it was sensible to conduct a test to ensure the exogeneity of current inspections.

3.2.2 Exogeneity of Inspections

In order to fix the above problem, we looked for another variable (instrument variable) to model inspections that did not enter the basic model[13]. A good instrument variable would be one that affected the dependent variable only through the endogenous variable. Citizens' complaints appeared to be a good candidate as citizens' complaints were made directly to environmental authorities and not to plants. Hence although citizens' complaints may influence plant pollution reporting, it would only be due to inspections conducted by environmental authorities in response to such complaints. We

[13] One approach was to remove contemporaneous/current inspections from the model (Magat and Viscusi 1990). Another approach was to use inspections from past periods as the instrument variable (Laplante and Rilstone 1996).

ran a simple regression in which we put both inspections and citizens' complaints as regressors. The results are shown in the Appendix 2. Citizens' complaints turned out to have no significant direct impact on pollution reporting by the firms. On the other hand, citizens' complaints were positively correlated with inspections (correlation coefficient: 0.3174). Hence, we could build a model that simultaneously involved both the inspections equation and the pollution emissions equation with citizens' complaints appearing in the former but not in the latter. The model is given below:

$$INS_{i,t} = c + \alpha_1 CMP_{i,t} + \alpha_2 INS_{i,t-1} + \alpha_3 OPT_{i,t} + \alpha_4 AGE_i + \alpha_5 EMP_i + \alpha_6 RATE_i + \mu SEC_i + \theta OWN_i + \sigma_{i,t}$$
$$Z_{i,t} = c + \beta_1 INS_{i,t} + \beta_2 INS_{i,t-1} + \beta_3 OPT_{i,t} + \beta_4 AGE_i + \beta_5 EMP_i + \beta_6 RATE_i + \gamma SEC_i + \delta OWN_i + \varepsilon_{i,t}$$

(Equations 3 & 4)

where $CMP_{i,t}$ denotes the number of citizens' complaints against plant i in period t. $Z_{i,t}$ here only refers to plant COD discharge but not TSS discharge because there were no significant impacts of inspections on TSS discharge as shown from our OLS estimations. The Wald test using citizens’ complaints as the instrument variable strongly rejected the hypothesis of the exogeneity of inspections (Wald's statistics: 45.32).

We used two-staged least-square (2SLS) estimations. Estimation residuals are usually assumed to be identically and independently distributed (IID). However, in our model, the IID assumption was too strong, so we relaxed the assumption by allowing the distribution of residuals not to be necessarily identical for each plant (cluster robust with plants). The results of the first stage (inspection equation) are reported in Table 4, while the results of the second stage (emission equation) can be found in Table 5.

The regression results of the first stage using the inspections equation revealed the inspection strategies of the environmental agency (FEPB). Firstly, larger polluters were more likely to be inspected than smaller ones. This was supported by the following observations: the coefficient estimates for the output value were positive and strongly significant; the plants in the medicine sector attracted many more inspections than plants in the other sectors; and inspections on state-owned plants (usually large polluters) were more frequent than on plants with other kinds of ownership. Secondly, one-period lagged inspections had a significantly persistent effect on current inspections in that firms were more likely to be inspected in the current period if they had been inspected in the last period. Thirdly, older plants were more likely to be inspected. Finally, citizens' complaints had a strong effect on inspections, a fact which was confirmed by our conversations with FEPB employees in that inspections were also triggered by citizens’ complaints.

Table 4. Results of the first stage (using the inspection equation)

(Sample size: 411)

Independent Variable	**INS_t**
Complaint	1.6014***
	(0.0512)
INS_{t-1}	0.1832***
	(0.0512)
OPT_t	0.0433***
	(0.0135)
AGE	0.2090***
	(0.0667)
EMP	0.0001
	(0.0003)
Rate	0.4837***
	(0.1537)
Food	-0.9097***
	(0.2253)
Paper	-0.8997***
	(0.2448)
Chemical	-0.5119**
	(0.2086)
State-owned	0.0319
	(0.1954)
Collective	0.0075
	(0.1573)
Constant	1.3551***
	(0.2774)
R^2	0.4929

Note: The second row for each variable shows the standard deviations.

As for the emissions equation, the results were similar to those obtained in the basic model. However, here, current inspections appeared to have more impact on verified pollution figures. Current inspections increased verified absolute and relative COD discharge levels by 8.26% and 7.91%, respectively.

Table 5. Results of the second stage (using the emissions equation)

(Sample size: 411)

Independent	**COD Discharges**	
Variable	**Absolute**	**Relative**
INS_t	4.5900**	2.7488*
	(2.0753)	(1.4348)
INS_{t-1}	-0.6754	-0.8445
	(1.534)	(1.0935)
OPT_t	6.7861***	3.9677***
	(0.9446)	(0.7706)
AGE	0.5318	0.7983
	(2.101)	(1.461)
EMP	-0.0009	0.0028
	(0.0129)	(0.0102)
Rate	-7.6504	-4.1209
	(4.9778)	(3.2953)
Food	-35.4238**	-25.1604**
	(14.0931)	(10.3594)
Paper	-32.2003**	-26.3727***
	(12.4133)	(9.969)
Chemical	-27.7196**	-19.0473**
	(13.1287)	(9.6395)
State-owned	14.5182**	6.5836
	(6.7465)	(5.1723)
Collective	9.6919*	5.9669*
	(5.3236)	(3.5315)
Constant	10.9002	9.5854

	(16.5708)	(12.2995)
R^2	0.8191	0.7647

Note: The second row for each variable shows the standard deviations.

3.2.3 Comparison with Previous Studies

In this part, we present how and why our results are different from previous studies on this topic. Our regression results are very different from those of Magat and Viscusi (1990) and Laplante and Rilstone (1996) whose studies were based on US and Canadian cases where inspections were shown to reduce actual plant pollution levels by 20% and 28%, respectively, while in this study, inspection increased verified emission levels by 8.26% (namely, by way of increasing the pollution levies paid by the plants). Therefore, in China, firms tend to under-report their pollution but in the US and Canada, plants do not systematically do this. This drastic difference can be explained by the different institutional arrangements between China, and the US and Canada, in terms of environmental regulations and enforcement.

China's environmental regulations are mainly based on pollution taxation/fees, while the US and Canada mainly use standards to control pollution. With taxation, the target of inspections is to make plants pay levies according to their actual emissions, but with standards, inspections aim at inducing plants to keep their emissions within the standards set. Thus, different regulations create different goals for the inspectors.

In China, plants usually face only a limited monetary penalty for under-reporting their emissions, unlike in the US and Canada where fraudulent reporting is a serious criminal offense. As mentioned earlier, having a limited monetary penalty tempts firms into juggling the cost of non-compliance against the cost of the levies. However, in the US and Canada, plants prefer to report the truth even if they do not comply with the standards because the penalty for non-compliance is much less than for fraudulent reporting.

Another factor is that in China, plants are required to make ex-ante self-reports while in the US and Canada, plant self-reports are ex-post. China's specific procedures give plants incentives to under-report their emissions. For instance, plants can just predict lower emission estimates in their reports at the beginning of the year and then decide whether to modify these depending on how many inspections are imposed on them.

Finally, inspections made by China's environmental authorities are seemingly just to verify plant-reported emissions figures, while inspections conducted by US and Canadian environmental agencies provide a deterrent to non-compliance with the standards. For instance, in our data, the average number of inspections per quarter was 2.19 per plant. However, in Magat and Viscusi (1990) and Laplante and Rilstone (1996), the corresponding numbers were 0.044 and 0.128, respectively. Moreover, one-period lagged inspections showed no significant effect on plants' self-reports in our study, but in Magat and Viscusi (1990) and Laplante and Rilstone (1996), past inspections had a strong influence on the firms' current state of compliance. There was also a difference in the inspection strategies of the environmental agencies: one-period lagged inspections showed a significantly persistent carry-over effect on current inspections in our case, while the probability of a current inspection was a decreasing function of past inspections in Laplante and Rilstone (1996). This implies that environmental agencies in China target the verification of reports whereas the environmental authorities in Canada prioritize deterrence.

Based on above considerations, we treated the self-reported emissions data from the firms in our study on a prima facie basis, unlike Magat and Viscusi (1990) and Laplante and Rilstone (1996) who treated these reports as equivalent to the actual figures. Hence, we explain our regression results as inspections increasing plants' verified pollution levels by 8.26%, while Magat and Viscusi (1990) and Laplante and Rilstone (1996) respectively concluded that inspections reduced plants’ actual pollution emissions by 20% and 28%.

Our results are also different from those of Dasgupta et al. (2001), even though we both use data from China. According to Dasgupta et al.’s (2001) results, current year inspections reduced plants' verified pollution levels by a very small degree (0.40% for COD). The possible reasons of this difference are as follows. First of all, their data was yearly-based while ours was quarterly-based. Since field inspections have strong immediate effects, an inspection that happened a year ago may not influence a firm’s current decisions at all. Secondly, the dataset in Dasgupta et al. (2001) included plants that did not pay levies (57% of the total sample). Since plants only paid levies for one of their pollutants, there were even fewer samples that paid levies on their COD or TSS emissions which Dasgupta et al. (2001) used as dependent variables. Therefore, their sample size was very limited. Finally, in Dasgupta et al. (2001), the dependent variables (COD and TSS emissions) were measured only as the levels of discharge relative to the respective standards while absolute emission levels were not taken into account, whereas in this study, both were used.

4. CONCLUSIONS

We adopted a unique dataset derived from the FEPB, China, in which we only included plants that paid environmental taxes on a specific pollutant (COD). By acknowledging the fact that their real pollution levels were unobservable, we simply treated the verified pollution figures as the actual. We provided clear empirical evidence that inspections conducted by environmental agencies significantly and positively increased the verified absolute and relative COD emission levels of the sampled plants by 8.26% and 7.91%, respectively. This is strong evidence that plants under-report their pollution emissions.

Our results are in contrast with similar studies in the US and Canada. The institutional aspects of China's environmental regulations explain the differences well. In particular, the US and Canada implement pollution standards while China uses pollution taxation. Moreover, China fails to provide plants with a strong incentive to report their emissions truthfully through setting limited monetary penalties for fraudulent reporting and its system of ex-ante self-reporting. Our results are also different from similar previous studies in China, the main reason being that our sample consisted only of plants that paid environmental levies.

Our study has key policy implications. In particular, the impact of enforcement actions on the environmental performance of polluters depends heavily on the environmental regulations themselves. China's regulations make environmental enforcement actions effective mainly in verifying pollution reports made by plants but not in reducing their actual levels of pollution. In order to effectively control and reduce pollution, a reform of the existing regulations is essential.

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APPENDICES

Appendix 1. Inter-Plant and Intra-Plant Effects
(Sample size: 137)

Independent Variable	Average COD Discharge	
	Absolute	Relative
Average INS_t	2.0816	0.2722
	(2.9209)	(2.0968)
Average OPT_t	6.9003***	4.0729***
	(0.4946)	(0.3551)
AGE	1.0743	1.2654
	(2.4641)	(1.7689)
EMP	-0.001	0.0028
	(0.0111)	(0.008)
Rate	-6.6513	-3.2481
	(5.6359)	(4.0458)
Food	-37.4749***	-26.9390***
	(8.4423)	(6.0603)
Paper	-34.0759***	-27.9485***
	(9.0473)	(6.509)
Chemical	-28.5390***	-19.7829***
	(7.5603)	(5.4272)
State-owned	14.8131**	6.9699
	(6.9973)	(5.0231)
Collective	9.7433*	6.02
	(5.635)	(4.0451)
Constant	14.1364	12.3332
	(10.5967)	(7.6069)
R^2	0.8224	0.7681

Note: The second row for each variable shows the standard deviations.

Appendix 2. Results of Emissions Equations (OLS With Citizens' Complaints)
(Sample Size: 411)

Independent Variable	**COD Discharges**	
	Absolute	**Relative**
Complaint	4.7478	3.0906
	(4.2267)	(3.0552)
INS_t	1.6252	0.8188
	(1.0124)	(0.7249)
INS_{t-1}	-0.1321	-0.4908
	(1.0514)	(0.7529)
OPT_t	6.9147***	4.0513***
	(0.2766)	(0.198)
AGE	1.1516	1.2017
	(1.3652)	(0.9776)
EMP	-0.0007	0.0029
	(0.0063)	(0.0045)
Rate	-6.2163**	-3.1873
	(3.1472)	(2.2536)
Food	-38.1208***	-26.9163***
	(4.648)	(3.3282)
Paper	-34.8677***	-28.1090***
	(5.033)	(3.6039)
Chemical	-29.2371***	-20.0351**
	(4.2506)	(3.0437)
State-owned	14.6128***	6.6452**
	(3.9516)	(2.8296)
Collective	9.7142***	5.9814***
	(3.1814)	(2.2781)
Constant	14.9177***	12.2005***
	(5.7753)	(4.1355)
R^2	0.8229	0.7688

Note: The second row for each variable shows the standard deviations.